

QUALITY OF SERVICE ENHANCEMENTS
FOR WIRELESS COMMUNICATIONS SYSTEMS

CROSS REFERENCE TO RELATED APPLICATIONS

5 This application claims priority under 35 U. S. C. § 119(e) to United States Provisional Patent Application No. 60/169,814, filed December 8, 1999, by William C. Y. Lee and David J. Y. Lee, and entitled "CELLULAR IP FEATURES AND PROTOCOLS," attorneys' docket number G&C 139.146-US-P1, which application is incorporated by reference herein.

10 This application is related to the following co-pending and commonly-assigned U.S. Patent Applications:

Serial Number --/---, ---, filed on same date herewith, by Jau Young Lee and William C. Y. Lee, entitled "TUNNELLING WIRELESS VOICE WITH SOFTWARE-DEFINED VOCODERS," attorneys' docket number G&C 139.146-US-U1;

15 Serial Number 09/620,639, filed July 21, 2000, by Jau Young Lee and William C. Y. Lee, entitled "TUNNELLING VOICE OVER THE INTERNET PROTOCOL IN A CELLULAR NETWORK," attorneys' docket number G&C 139.135-US-U1;

20 Serial Number 09/590,346, filed June 8, 2000, by David J. Y. Lee, Ce Xu, and William C. Y. Lee, entitled "MOBILE INTERNET PROTOCOL SQUARE," attorneys' docket number G&C 139.133-US-U1; and

Serial Number 09/589,974, filed June 8, 2000, by David J. Y. Lee, Ce Xu, and William C. Y. Lee, entitled "ARCHITECTURE OF INTERNET PROTOCOL-BASED CELLULAR NETWORKS," attorneys' docket number G&C 139.132-US-U1;

all of which applications are incorporated by reference herein.

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BACKGROUND OF THE INVENTION

1. Field of the Invention.

The present invention relates to wireless communications systems, and, in particular, to various techniques for enhancing the quality of service on wireless communications systems.

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2. Description of the Related Art.

Wireless telecommunications technology has been widely adopted for voice applications. Currently, wireless telecommunications technology is gaining momentum in the telecommunications industry for other wireless applications as well, such as data 5 communications. However, voice and data applications place different demands on wireless networks, and require different strategies for ensuring a high quality of service (QoS).

Moreover, wireless networks are beginning to migrate to Internet Protocol (IP) networks for their underlying infrastructure. IP networks have certain advantages over present wireless networks. For example, it is easier to deploy IP networks. In addition, IP 10 networks are more cost-effective in providing wireless services.

Traffic on Internet Protocol (IP) networks, such as the Internet or Intranets, is growing at an exponential rate, as peoples' lives become more tightly interconnected with these networks. Thus, the ability to keep connected with IP networks while mobile is highly desirable. The present invention provides a number of features and functions that enhance 15 the quality of service (QoS) available on IP networks.

SUMMARY OF THE INVENTION

To overcome the limitations in the prior art described above, and to overcome other limitations that will become apparent upon reading and understanding the present 20 specification, the present invention discloses various techniques for enhancing the quality of service on wireless communications systems. These techniques determine when errors occur in transmitted frames, then apply Bit Error Rate Power Control, Power-Based Re-Transmission, and Sub-Frame Selective Repeat methods to these errors. Consequently, the handling of frame errors consumes fewer resources in the wireless communications systems.

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BRIEF DESCRIPTION OF THE DRAWINGS

Referring now to the drawing in which like reference numbers represent corresponding parts throughout:

FIG. 1 illustrates an exemplary network configuration that could be used to 30 implement the preferred embodiment of the present invention;

FIG. 2 is a block diagram that illustrates an exemplary network protocol that could be used to provide third-generation (3G) wireless communications for the cellular networks, including both voice and data, according to the preferred embodiment of the present invention;

5 FIG. 3 is a block diagram that illustrates an exemplary frame transmitted by the network protocol according to the preferred embodiment of the present invention;

FIG. 4 is a flowchart that illustrates the logic of the bit error rate power control method according to the preferred embodiment of the present invention;

10 FIG. 5 is a block diagram that illustrates a circular buffer used by the radio link protocol module according to the preferred embodiment of the present invention;

FIGS. 6A-6D are charts that illustrate how the increase in transmit power is used in an attempt to eliminate errors and ensure the correct reception of frames according to the preferred embodiment of the present invention;

15 FIG. 7 is a flowchart that illustrates the logic of the power-based re-transmission method according to the preferred embodiment of the present invention;

FIG. 8 is a block diagram that illustrates an exemplary frame transmitted by the network protocol according to the preferred embodiment of the present invention, wherein the frame includes a header, data portion, cyclic redundancy check, and an indicator field (which may be part of the header or the data portion); and

20 FIG. 9 is a flowchart that illustrates the logic of the sub-frame selective repeat method according to the preferred embodiment of the present invention.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT

In the following description of the preferred embodiment, reference is made to the
25 accompanying drawings that form a part hereof, and in which is shown by way of illustration a specific embodiment in which the invention may be practiced. It is to be understood that other embodiments may be utilized and structural changes may be made without departing from the scope of the present invention.

Environment

FIG. 1 illustrates an exemplary network configuration that could be used to provide inter-network communications. This exemplary network configurations may be comprised of interconnected cellular networks (e.g., AMPS, GSM, TDMA, or CDMA cellular networks), public land mobile networks (PLMNs), public switched telephone networks (PSTNs), and Internet Protocol (IP) networks.

In the example of FIG. 1, a cellular network 100 includes at least one MSC (Mobile Switching Center) 102, at least one BSC (Base Station Controller) 104, and at least one BTS (Base Transceiver Station) 106 for communicating with one or more handsets 108 or other transceivers. The BSC 104 includes a vocoder 110 for encoding and decoding voice signals received from and sent to the handset 108.

The MSCs 102 of two different cellular networks 100 each connects to a separate Gateway 112 that interfaces into an IP network 114. In this manner, the cellular networks 100 communicate across the IP network 114. Also, in one embodiment, the cellular networks 100 themselves may be IP networks.

Network Protocol

FIG. 2 is a block diagram that illustrates an exemplary network protocol 200 that could be used to provide third-generation (3G) wireless communications for the cellular networks 100, including both voice and data, according to the preferred embodiment of the present invention. In one embodiment, the protocol 200 may comprise the CDMA 2000 protocol, which is further described at www.3gpp2.org, the web site for the Third-Generation Partnership Project number 2 (3GPP 2).

This protocol 200 loosely follows the OSI (Open System Interconnection) model, in that it is comprised of seven layers: Application (7), Presentation (6), Session (5), Transport (4), Network (3), Data Link (2), and Physical (1). Control is passed from one layer to the next, starting at the Application layer in one station, proceeding to the Physical layer, over the channel to the next station, and back up the layers from the Physical layer to the Application layer.

In the illustration of FIG. 2, note that layers 3-7 are grouped together, and include modules for Upper Layer Signaling 202, Data Services 204, and Voice Services 206.

Layer 2 includes a Link Access Control (LAC) module 208 and a Medium Access Control (MAC) module 210. The MAC 210 includes modules for MAC Control States 212, Radio Link Protocol (RLP) 214, and Multiplexing 216. The Multiplexing module 216 includes a module for Quality of Service (QoS) Control 218. Layer 2 is responsible for node 5 to node validity and integrity of the transmission.

Finally, Layer 1 comprises a Physical Layer 220. In this embodiment, the Physical Layer 220 is also known as an “air link” or “air interface,” which generically describes the radio frequency (RF) transmissions. The Physical Layer 220 is responsible for transmitting and receiving bits across the air link. However, this layer 220 has no understanding of the 10 meaning of the bits, but deals merely with the electrical and radio frequency characteristics of the signals and signaling methods. For example, the Physical Layer 220 in the transmitting station is presented a frame and transforms it into an over-the-air waveform, while the Physical Layer 220 in the receiving station transforms the waveform back into a frame.

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Bit Error Rate Power Control

The Radio Link Protocol (RLP) module 214 needs to be aware of the performance on the air link and adjust accordingly for better bit error rates (BER). The prior art uses cyclic redundancy checks (CRC) to determine whether any bits within a frame are in error.

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However, the total BER for the frame cannot be determined, since the CRC can only identify whether a frame includes any bits in error, but it does not have the capability to identify how many bits are in error.

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The present invention, on the other hand, calculates and/or estimates the BER for a portion of a frame or the entire frame itself, which is then used to provide a QoS assessment for the air link. Once the BER is calculated and/or estimated, adjustments can be made to the transmit power for the air link. This is described in conjunction with FIG. 3.

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FIG. 3 is a block diagram that illustrates an exemplary frame 300 transmitted by the network protocol 200 according to the preferred embodiment of the present invention, wherein the frame includes a header 302, data portion 304, padding portion 306, and CRC 308. The BER estimate is performed by replacing the header 302, or other fields, within a frame 300 with an orthogonal code, wherein the BER for the orthogonal code can then be

calculated. A table 310 that associates headers 302 to orthogonal codes 312 may be used to map between the actual header 302 and the specific orthogonal code 312. Preferably, the header 302 is mapped to the specific orthogonal code 312 at call set up, and the orthogonal code 312 is used thereafter in place of the header 302 during transmissions.

5 This orthogonal code 312 makes it easier to calculate and/or estimate the BER. Specifically, because the orthogonal code 312 is a fixed pattern, an exact calculation can be made of the BER within the orthogonal code 312 itself. Thereafter, the BER of the entire frame 300 can be estimated using extrapolation. Once the BER is calculated for the orthogonal code 312 alone, or estimated for the entire frame 300, the transmit power can be
10 adjusted accordingly. Moreover, the mobile phone 108 and/or the network components 102, 104, 106 can perform this BER analysis, and control their own transmit power, or the transmit power of the other side of the communications channel, accordingly.

In an alternative embodiment, the orthogonal code 312 could replace padding bits 306 within the frame 300. Thereafter, the orthogonal code 312 would be used in a manner
15 as described above to perform BER analysis.

FIG. 4 is a flowchart that illustrates the logic of the BER power control method according to the preferred embodiment of the present invention.

Block 400 represents the receiving station determining the BER for an orthogonal code 312 included in a frame 300 transmitted by the wireless communications system 100.

20 This information is then communicated to the transmitting station.

Block 402 represents the transmitting station adjusting its transmit power for the re-transmission of the frame 300, as well as the transmission of subsequent frames 300, based on the BER determined by the receiving station.

25 Power Based Re-Transmission

The RLP module 214 is responsible for making “best effort” deliveries of frames to the upper layers 202 of the protocol 200. The term “best effort” means that a frame received with errors will be acknowledged and asked to be retransmitted again. If the frame is received with errors after two tries, then it is delivered to the upper layers 202 of the
30 protocol 202 for further action. Preferably, frames that are re-transmitted because of errors should be transmitted with higher power to ensure the error-free reception of the frame.

FIG. 5 is a block diagram that illustrates a circular buffer 500 used by the RLP module 214 according to the preferred embodiment of the present invention, wherein the circular buffer 500 stores “N” frames 502 (which in this illustration comprises 8 frames, although the dotted line between frame #6 and frame #N-1 is intended to indicate that the 5 buffer 500 could store any number “N” of frames 502). The circular buffer 500 is also known as a “sliding window” for the reception of frames 502.

If, for example, a frame 502 with errors is received, it is important to clear the error, re-transmit and receive a valid version of the frame 502 into the circular buffer 500, and then remove it from the circular buffer 500 and pass it onto the upper layers 202 of the protocol 10 200, so that additional frames 502 can be subsequently received into the circular buffer 500. Because of the structure of the circular buffer 500, if an error occurs at the frame #2, it is important to get the error cleared, so that the circular buffer 500 can still work effectively; on the other hand, at frame #N, the error transmission has less impact on the operation and resources of the circular buffer 500.

FIGS. 6A-6D are charts that illustrate how the increase in transmit power is used in an attempt to eliminate errors and ensure the correct reception of frames 502 according to the preferred embodiment of the present invention.

FIG. 6A illustrates how the transmit power increases with frame 502 number, e.g., transmit power increases as the amount of transmitted data increases.

FIG. 6B illustrates how the transmit power is immediately increased in the event that a frame 502 is received in error. Thus, when frame #5 is re-transmitted due to its reception with errors, it is immediately re-transmitted with higher power to ensure the error-free reception of frame #5.

FIG. 6C illustrates how the transmit power is increased by steps when the starting 25 frames 502 are received in error. If the first several frames 502 are received in error, the transmitting station steps up the transmit power immediately to avoid future resource problems.

FIG. 6D illustrates how the transmit power is immediately increased when the ending frames 502 are received in error. Thus, when frame #N-1 is re-transmitted due to its 30 reception with errors, it is transmitted with higher power to ensure the error-free reception of frame #N-1, as well as frame #N.

FIG. 7 is a flowchart that illustrates the logic of the power-based re-transmission method according to the preferred embodiment of the present invention.

Block 700 represents the receiving station determining whether a frame 502 transmitted by the wireless communications system 100 was received in error. This 5 information is then communicated to the transmitting station.

Block 702 represents the transmitting station immediately increasing its transmit power for the re-transmission of the frame 502, as well as the transmission of subsequent frames 502, based on the frame 502 position, i.e., the frame 502 number, the total amount of transmitted data, whether one or more starting frames 502 in the circular buffer 500 were 10 received in error, whether one or more ending frames 502 in the circular buffer 500 were received in error, etc.

Sub-Frame Selective Repeat

There are two standard error correction schemes used in data communications for 15 implementing error control, i.e., “go back n frames” (i.e., re-transmit the last n frames) and “selective repeat” (i.e., re-transmit only the frame with errors). It is generally believed that “selective repeat” is a more efficient scheme for re-transmitting frames with errors. However, the overhead associated with “selective repeat” can be quite significant, since every frame in error needs to be acknowledged before delivery to the upper layers 202 in the 20 correct order or sequence.

FIG. 8 is a block diagram that illustrates an exemplary frame 800 transmitted by the network protocol 200 according to the preferred embodiment of the present invention, wherein the frame includes a header 802, data portion 804, CRC 806, and an indicator field 808 (which may be part of the header 802 or the data portion 804). The present invention 25 enhances the traditional selective repeat scheme by performing a “sub-frame” selective repeat. Specifically, each of the bits in the indicator field 808 indicates the parity of some subset of bits in the data portion 804 of the frame 800 (e.g., each bit in a particular position of the indicator field 808 represents the parity for a subset of bits in the same relative position in the data portion 804 of the frame 800). When a parity error occurs as 30 determined by the bits in the indicator field 808, only the associated subset of bits in the data

portion 804 of the frame 800 need to be re-transmitted, rather than the entire frame 800 itself.

FIG. 9 is a flowchart that illustrates the logic of the sub-frame selective repeat method according to the preferred embodiment of the present invention.

5 Block 900 represents the receiving station determining whether a portion of the frame 800 transmitted by the wireless communications system 100 was received in error. As noted above, the frame 800 includes an indicator field 808 comprised of a plurality of bits and one of the bits in the indicator field 808 indicates a parity for the portion of the frame 800 received in error. This information is then communicated to the transmitting station.

10 Block 902 represents the transmitting station re-transmitting only the indicated portion of the frame 800 without re-transmitting the entire frame 800.

Conclusion

This concludes the description of the preferred embodiment of the invention. The 15 following describes some alternative embodiments for accomplishing the present invention.

Although the network configuration 100 shown in FIG. 1 is indicated as a preferred embodiment, other network configurations could be used as well. Those skilled in the art will recognize that any number of different network configurations could benefit from the present invention.

20 Although the CDMA 2000 protocol 200 shown in FIG. 2 is indicated as a preferred embodiment, any number of different protocols could be used with the present invention. Those skilled in the art will recognize that any number of different protocols could benefit from the present invention.

In yet another embodiment, circular buffers 500 need not be used. Those skilled in 25 the art will recognize that any number of different buffers and memory management techniques could benefit from the present invention.

In still another embodiment, different power control methods could be used. The present invention is not intended to be limited to only the methods described herein.

30 In an alternative embodiment, different ways of indicating sub-frame errors could be used. The present invention is not intended to be limited to only the methods described herein.

In summary, the present invention discloses various techniques for enhancing the quality of service on wireless communications systems. These techniques determine when errors occur in transmitted frames, then apply Bit Error Rate Power Control, Power-Based Re-Transmission, and Sub-Frame Selective Repeat methods to these errors. Consequently,
5 the handling of frame errors consumes fewer resources in the wireless communications systems.

The foregoing description of the preferred embodiment of the invention has been presented for the purposes of illustration and description. It is not intended to be exhaustive or to limit the invention to the precise form disclosed. Many modifications and variations
10 are possible in light of the above teaching. It is intended that the scope of the invention be limited not by this detailed description, but rather by the claims appended hereto.